Changes in the Aquatic Plant Community of Pike Lake, Marathon County, 1989-2002

MWBC: 1406300

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EXECUTIVE SUMMARY

Pike Lake is a eutrophic/mesotrophic, hardwater lake with good water quality and fair-to-poor clarity. Nutrients and algae increase during the summer, likely due to the chemical treatments that leave plant material in the water to decay.

Aquatic plant growth in Pike Lake is favored by the shallow depths, the gradually slope, hardwater, favorable silt sediments and abundant nutrients.

The aquatic plant community in Pike Lake is characterized by good species diversity, average quality, above average amount of disturbance, abundant frequency of plants and low density of plant growth. The dominant plant species in 2002 were *Chara* sp. and *Ceratophyllum demersum*.

Aquatic plants are distributed throughout the lake, up to a maximum rooting depth of 13 feet. The depth zone of most abundant plant growth has shifted from the 1.5-5ft depth zone in 1989-96 to the 5-10ft depth zone in 1999-2002. Aquatic plant growth is sparser in the southeast half of the lake.

The composition of the aquatic plant community in Pike Lake has changed significantly and the total occurrence and density of aquatic plant growth has increased.

Some changes in the aquatic plant community are disturbing:

1) The dominant species in the plant community have shifted to species favored by disturbance and poor water clarity.
2) A non-native plant species, curly-leaf pondweed has increased.
3) Species diversity has decreased since 1989.
4) Disturbance in Pike Lake has increased.
5) The quality of the plant community has decreased (AMCI).
6) Coverage of free-floating plant species have increased (50%)
7) Some native pondweeds have declined.

Management Recommendations

1) Establish buffer zones of natural vegetation around the lakeshore.
2) Plant emergent aquatic plants to replace rip-rap.
3) Cooperate with efforts in the watershed to reduce erosion and fertilizer run off into Pike Lake.
4) Eliminate fertilization of shoreline properties.
5) Sediment analysis must be conducted in Pike Lake before any project involving the sediments.
6) Explore alternatives to the use of broad-spectrum chemicals for native aquatic plant control.

I. INTRODUCTION

Studies of the aquatic plants (macrophytes) in Pike Lake were conducted July 1989, August 1993 and July 1996 by Water Resources staff of the North Central District - Department of Natural Resources (DNR) and in June of 1999 and 2002 by Waters staff of the West-Central Region and Central Wisconsin Basin of the DNR. The surveys are conducted as part of a Long Term Trend Study involving lakes throughout the state. Aquatic plant data is collected every three years and water quality data is collected every year on these trend lakes.

Long term studies of the diversity, density, and distribution of aquatic macrophytes are ongoing and will provide information that will be valuable for decisions about fish habitat improvements, designation of sensitive wildlife areas, water quality improvement and aquatic plant management. Trend data can reveal changes occurring in the lake ecosystem.

Background

Pike Lake is a 205-acre natural hardwater lake in eastern Marathon County (Appendix XVII) with a maximum depth of 34 feet. Water enters the lake from Rice Lake Creek on the north shore and flows out to Pike Creek on the south shore. The watershed is of moderate size, but a large portion is in agriculture (cite?).

History

Pike Lake has a long history of chemical treatments to reduce plant and algae growth. Treatments for algae growth have been carried out since 1940, but records of actual chemical usage have been regularly recorded only since 1949. There were probably unrecorded treatments carried out during the 1940's, so the total amount of chemicals used is likely higher than recorded.

During the years 1942-2002, 14,765 pounds of copper sulfate and 304 gal of Cutrine has been applied to Pike Lake for algae control (Table 1). This means that 3748 pounds of pure elemental copper has gone into Pike Lake. Copper does not degrade any further and remains in the lake sediments, toxic to aquatic life.

During 1949-64, 3560 pounds of Arsenic has been added to Pike Lake (Table 1). Arsenic is highly toxic and does not degrade. The arsenic contaminated sediments must be handled as hazardous waste.

Silvex (2,4,5-TP) was applied to Pike Lake during 1968-1969 in the amount of 139.5 pounds (Table 1). Silvex is no longer approved for aquatic use due to its toxicity.

Endothall Acid has added to Pike Lake in several forms: as granular Aquathol (6345 pounds), liquid Aquathol (697 gallons) and as Hydrothol (4560 pounds). Hydrothol is the monoamine salt formulation and is more detrimental to young fish (Table 1).

Table 1. Aquatic Herbicides Applied to Pike Lake, 1942-2002.

	Copper Sulfate pounds	Cutrine gallons	Arsenic pounds	Silvex 2,4,5-TP	Aquathol pounds	Aquathol gallons	Hydrothol pounds	2, 4-D pounds	Rodeo ounces	Diquat gallons
1942	1100									
1944	440									
1949	1000		110							
1950	1000		150							
1951	850									
1952	1000									
1960			600							
1963	850		1260							
1964	1600		1440							
1965	800									
1966	800									
1967	1900							440		
1968	750			67.5	1350					
1969	1125			72		51				
1970	750				1125					
1971					150					
1973					1010					
1974	300				1060					
1975					350					
1976							870			
1977							415			
1978							300	30		
1979							750	30		
1980					500		1500	10		
1981								10		
1982					550		650	20		
1983	500					24		5		8
1984								10		
1990		50				102	40		15	19
1991		38.75				68.5			3	11.5
1992		14.5				88.5			6	5
1993		39.75				38.5				14.75
1994		20.5			250	36.5	35		3	17
1995		36.5				52.5				12.75
1996		11.5				8.75				4.5
1997		21				42.25				10
1998		18.75				45.5			1	9.5
1999		17.5				37			3	11.25
2000		12.5				30.75			5	17
2001		10				33.5				11.5
2002		13.25				37.5			6	11.75
Totals	14765	305	3560	140	6345	697	4560	555	42	164

II. METHODS

Field Methods

The same study design was used for the 1989, 1993 and 1996 macrophyte studies and was based on the rake-sampling method developed by Jessen and Lound (1962). The 1999 and 2002 studies were slightly different in that the transects included sample sites in the 10-20ft depth zone.

The same transects were used during each survey. Twenty-one equal-distance transect lines were placed perpendicular to the shoreline with the first transect being randomly placed.

One sampling site was randomly located in each depth zone (0-1.5ft, 1.5-5ft, and 5-10ft). A site in the 10-20ft was added to each transect in 1999 and 2002. Using a long-handled rake, four rake samples were taken at each sampling site. The four samples were taken at each quarter of a 6-foot square quadrat. The aquatic plant species that were present on each rake sample were recorded. The species recorded includes aquatic vascular plants and several types of algae that have morphologies similar to vascular plants, such as muskgrass and nitella.

Each species was given a density rating (0-5) based on the number of rake samples on which it was present, at each sampling site.
A rating of 1 indicates that a species was present on one rake
A rating of 2 indicates that a species was present on two rake samples
A rating of 3 indicates that a species was present on three rake samples
A rating of 4 indicates that a species was present on all four rake samples
A rating of 5 indicates that a species was abundantly present on all rake samples at that sampling site.
The presence of filamentous algae was also noted in 1999 and 2002. The sediment type was recorded at each sample site.

The type of shoreline cover was recorded at each transect. A section of shoreline, 50 feet on either side of the transect intercept with the shore and 30 feet deep, was evaluated. The percentage of each cover type within this 100' x 30' rectangle was recorded and verified by a second researcher.

Specimens of all plants present were collected and saved in a cooler for later preparation of voucher specimens. Nomenclature was according to Gleason and Cronquist (1991).

Data Analysis

The data for each year was analyzed separately and compared. The percent frequency of occurrence of each species was calculated (number of sampling sites at which it occurred/total number of sites) (Appendices I-V). Relative frequency was calculated (number of occurrences of a species / all species occurrences) (Appendices I-V). The mean density was calculated for each species (sum of a species' density ratings/number of sampling sites) (Appendices VI-X). Relative density was calculated (sum of a species' density ratings / sum of all plant densities). A "mean density where present" was calculated (sum of a species' density ratings/number of sampling sites at which it occurred)(Appendices VI-X). The relative frequency and relative density were summed to obtain a dominance value (Appendices XI-XV).

Simpson's Diversity Indices ($1-\text{sum}(\text{relative frequencies})^2$) were calculated for each sampling year (Appendices I-V). Each sampling year was compared by a Coefficient of Community Similarity, measuring the percent similarity between two communities.

The Aquatic Macrophyte Community Index (AMCI) (Weber et. al. 1995) was applied to Pike Lake. Six parameters that characterize the aquatic macrophyte community (Table 10) are converted to a value 0 - 10.

The Average Coefficient of Conservatism and Floristic Quality were calculated to measure disturbance in the plant community (Nichols 1998). A coefficient of conservatism is an assigned value, 0-10, the probability that a species will occur in a relatively undisturbed habitat. The Average Coefficient of Conservatism is the mean of the coefficients of the species found in a lake. Floristic Quality Index is calculated from the Average Coefficient of Conservatism.

III. RESULTS

PHYSICAL DATA

Many physical parameters impact the macrophyte community. Water quality (concentration of nutrients and algae and water clarity, pH, hardness) influences the macrophyte community as the macrophyte community can in turn modify water quality. Lake morphology, sediment composition and shoreline land use also effect the macrophyte community.

WATER QUALITY

Algae, nutrients and water clarity are measured and combined to determine the trophic status of a lake (Table 2).
Oligotrophic lakes are low in nutrients and biomass.
Eutrophic lakes are high in nutrients and biomass and often experience algal blooms.
Mesotrophic lakes are intermediate in nutrient levels and biomass.

Table 2. Trophic Status

	Quality Index	Phosphorus ug/l	Chlorophyll ug/l	Secchi Disc ft.
Oligotrophic	Excellent	<1	<1	>19
	Very Good	1-10	1-5	8-19
Mesotrophic	Good	**10-30**	**5-10**	**6-8**
	Fair	30-50	10-15	5-6
Eutrophic	Poor	50-150	15-30	3-4
Hypereutrophic	Very Poor	>150	>30	>3
Pike Lake, 2002 Summer Mean	Good	23	6.5	5.6

After Lillie & Mason (1983) & Shaw et. al. (1993)

Phosphorus is a limiting nutrient in many Wisconsin lakes. Phosphorus is measured as an indication of the nutrients in a lake. The mean summer phosphorus in Pike Lake has varied between eutrophic and mesotrophic status (Figure 1). The lowest phosphorus levels were in 1995; the highest phosphorus levels were in 1997. Phosphorus concentrations have not changed significantly during the sampling years (Figure 1).

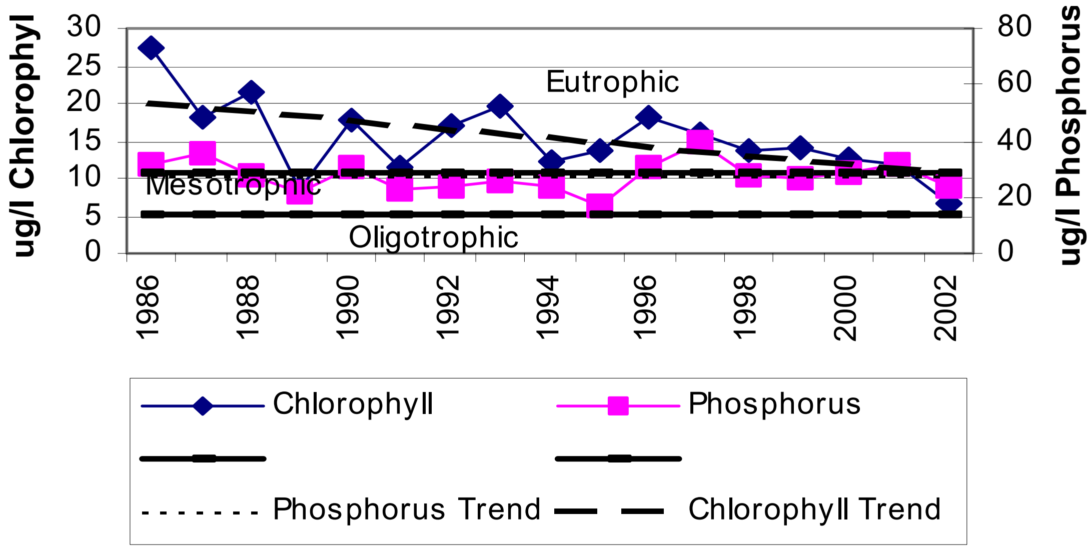

Figure 1. Summer mean phosphorus and chlorophyll in Pike Lake.

Algae are a natural and essential part of the food chain in a lake. However, prolonged algae blooms can inhibit the growth of submersed vegetation by reducing water clarity, and light availability.

Chlorophyll concentrations (which measure algae) have varied widely between years in Pike Lake, but have remained in the eutrophic range, except for 1989. The highest chlorophyll was recorded in 1986 (Figure 1). There has been a trend to decreasing chlorophyll in Pike Lake.

Water clarity, as measured with a Secchi Disc, has remained in the mesotrophic range during the study period and has not varied noticeably (Figure 2).

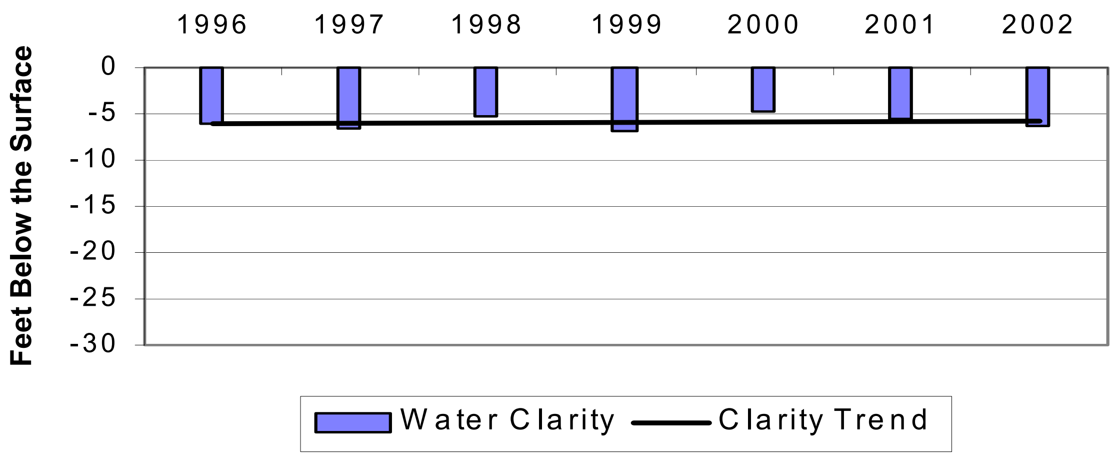

Figure 2. Summer mean water Clarity in Pike Lake.

Combination of phosphorus, chlorophyll and water clarity data indicate that Pike Lake is a eutrophic/mesotrophic lake with fair to poor water quality. This trophic state would support abundant plant and algae growth.

Lake Morphometry

Duarte and Kalff (1986) found that the slope of the littoral zone accounted for 72% of the observed variability in the growth of submergent vegetation. Gentle slopes support a broader zone of potential plant growth than steep slopes (Engel 1985).

The majority of the littoral zone in Pike Lake is gradually sloped, except for a section of the northeast shore that is steeply sloped. The deepest point of the lake lies near this shore.

Sediment Composition

Silt was the dominant sediment in Pike Lake, especially in the 5-20ft depth zone (Table 3). The occurrence of silt sediment increased dramatically with increasing depth. Another soft sediment, peat, was found only in the shallow zone at the Pike River inlet.

Sand was common, especially in the 0-5ft depth zone (Table 3). Sand mixed with silt or rock was also common in the 1.5-5ft depth zone.

Table 3. Pike Lake Sediment Composition by Depth Zone, 2002

		0-1.5′	1.5-5′	5-10′	10-20′	Overall
Soft Sediments	Silt	5%	19%	62%	81%	39%
	Silt/Muck			5%		1%
Mixed Sediments	Sand/silt	14%	24%	14%		14%
Hard Sediments	Sand	29%	38%	14%	12%	29%
	Sand/rock	15%	20%	5%	6%	11%
	Rock	20%				4%

The sediments recorded at the sample sites have been fairly consistent year-to-year (Table 4).

Table 4. Sediment Composition in Pike Lake, 1986-2002.

		1986	1993	1996	1999	2002
Soft Sediments	Silt	46%	48%	43%	44%	39%
	Silt/Muck					1%
Mixed Sediments	Sand/silt	7%	14%	13%	2%	14%
Hard Sediments	Sand	42%	25%	31%	35%	29%
	Sand/rock	1%	7%	10%	13%	11%
	Rock	3%	1%	3%	4%	4%

Shoreline Use

Land use activities strongly impact the aquatic plant community. Practices on shore can directly effect the plant community through increased sedimentation from erosion, increased nutrients from fertilizer run-off and soil erosion and increased toxics from farm and residential run-off.

Cultivated lawn was the most frequently encountered shoreline cover, with the highest mean coverage. Hard structures were common, found at nearly half the sites.

Herbaceous plants and wooded cover were commonly encountered at the transects but did not have a high mean coverage (Table 5).

Table 5. Shoreland Use, 2002

	Cover Type	Frequency of Occurrence at Transects	Mean % Coverage
Natural Shoreline	Native Herbaceous	52%	20%
	Wooded	47%	19%
	Shrub	19%	8%
	Total Natural		47%
Disturbed Shoreline	Cultivated Lawn	71%	46%
	Hard Structures	48%	5%
	Rip-rap	28%	2%
	Bare sand	5%	1%
	Pavement	5%	1%
	Total Disturbed		55%

Disturbed shoreline was encountered at 86% of the sites and covered 55% of the shoreline sites.

Some type of natural shoreline was found at 76% of the sites, but only had a mean coverage of 47%.

MACROPHYTE DATA

SPECIES PRESENT

A total of 38 different species of macrophytes was found during the 1989-2002 studies: 11 emergents speces, 6 floating leaf species, and 21 submergent species (Table 6).

No endangered of threatened species were found. One non-native species was found: *Potamogeton crispus.*

Table 6. Pike Lake Aquatic Plant Species, 1989-2002

Scientific Name	Common Name	I. D. Code
Emergent Species		
1) *Calla palustris* L.	water arm	calpa
2) *Carex rostrata* Stokes.	sedge	carro
3) *Dulichium arundinaceum* (L) Britton.	three-way sedge	dular
4) *Eleocharis palustris* (L.) R.& S.	creeping spikerush	elepa
5) *Equisetum fluviatie* L.	scouring rush	equfl
6) *Juncus* sp.	rush	junsp
7) *Pontederia cordata* L.	pickerelweed	ponco
8) *Sagittaria cristata* Engelm.	arrowhead	sagcr
9) *Sagittaria* sp.	arrowhead	sagsp
10) *Scirpus validus* Vahl.	softstem bulrush	sciva
11) *Typha latifolia* L.	broad leaf cattail	typla
Floating leaf Species		
12) *Brasenia schreberi* Gmel.	watershield	brasc
13) *Lemna minor* L.	small duckweed	lemmi
14) *Lemna trisulca* L.	forked duckweed	lemtr
15) *Nuphar variegata* Durand.	bull-head pond lily	nupva
16) *Nymphaea odorata* Aiton.	white water lily	nymod
17) *Spirodela polyrhiza* (L.) Schleiden.	great duckweed	spipo
Submergent Species		
18) *Ceratophyllum demersum* L.	coontail	cerde
19) *Chara* sp.	muskgrass	chasp
20) *Eleocharis acicularis* (L.) R.& S.	needle spikerush	eleac
21) *Elodea canadensis* Michx.	common waterweed	eloca
22) *Juncus pelocarpus* Mey.	rush	junpe
23) *Myriophyllum sibiricum* Komarov.	common water milfoil	myrsi
24) *Najas flexilis* (Willd.) Rostkov & Schmidt.	slender naiad	najfl
25) *Nitella* sp.	nitella	nitsp
26) *Potamogeton amplifolius* Tuckerman.	large-leaf pondweed	potam
27) *Potamogeton crispus* L.	curly-leaf pondweed	potcr
28) *Potamogeton foliosus* Raf.	leafy pondweed	potfo
29) *Potamogeton illinoensis* Morong.	Illinois pondweed	potil
30) *Potamogeton pectinatus* L.	sago pondweed	potpe
31) *Potamogeton praelongus* Wulf.	whitestem pondweed	potpr
32) *Potamogeton richardsonii* (Ar. Bennett) Rydb.	clasping-leaf pondweed	potri
33) *Potamogeton robbinsii* Oakes.	fern pondweed	potro
34) *Potamogeton zosteriformis* Fern.	flatstem pondweed	potzo
35) *Ranunculus longirostris* Godron.	stiff water crowfoot	ranlo
36) *Utricularia* sp.	bladderwort	utrsp
37) *Vallisneria americana* L.	water celery	valam
38) *Zosterella dubia* (Jacq.) Small.	water stargrass	zosdu

FREQUENCY OF OCCURRENCE

Myriophyllum sibiricum was the most frequent species in 1989, underwent cycles of increase and decrease (Konkel 2000) and became the third most frequent in 2002. *M. sibiricum* is still a common species in 1999 and 2002, increasing from 1999 (Figure 3).

Ceratophyllum demersum and *Lemna trisulca* increased dramatically from 1989 to become the most frequent species in 1993-1996 (Konkel 2000); *C. demersum* is still a commonly occurring species, increasing from 1999-2002 (Figure 3). *L.*

trisulca is less common and has decreased since 1999 (Figure 3).

Chara sp. was the most frequent species in 1999 and 2002 (44%, 49%) (Figure 3). The frequency of *Chara* had been cyclic during 1989-1996 (Konkel 2000).

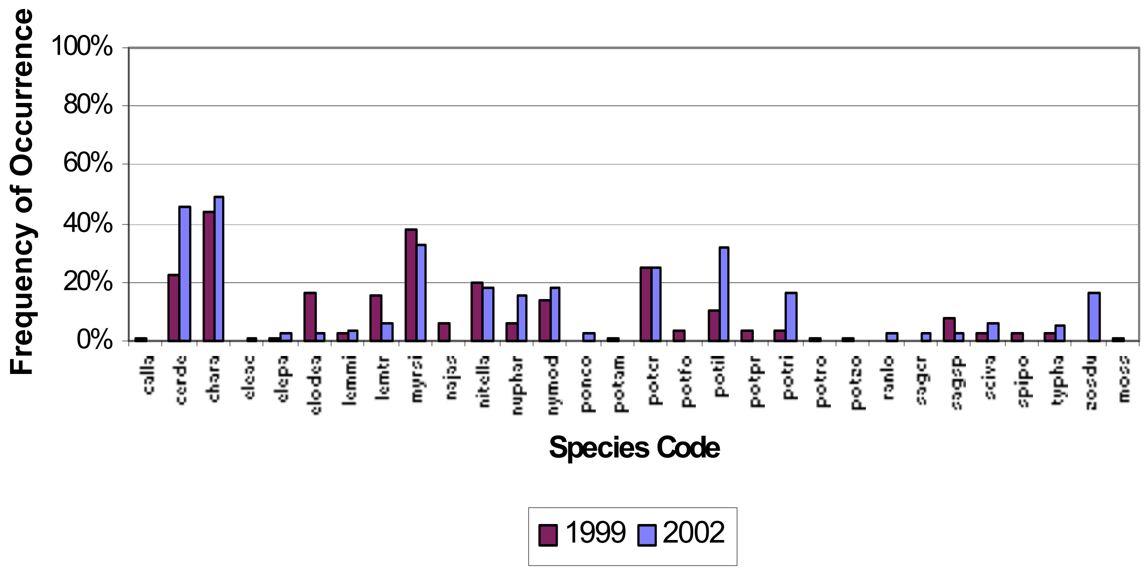

Figure 3. Frequencies of Prevalent Macrophyte in Pike Lake 1999-2002.

Filamentous algae was found at 23% of the sites in Pike Lake in 1999 and 19% of the sites in 2002. Filamentous algae occurred at its highest frequency in the 0-5ft depth zones (Figure 4).

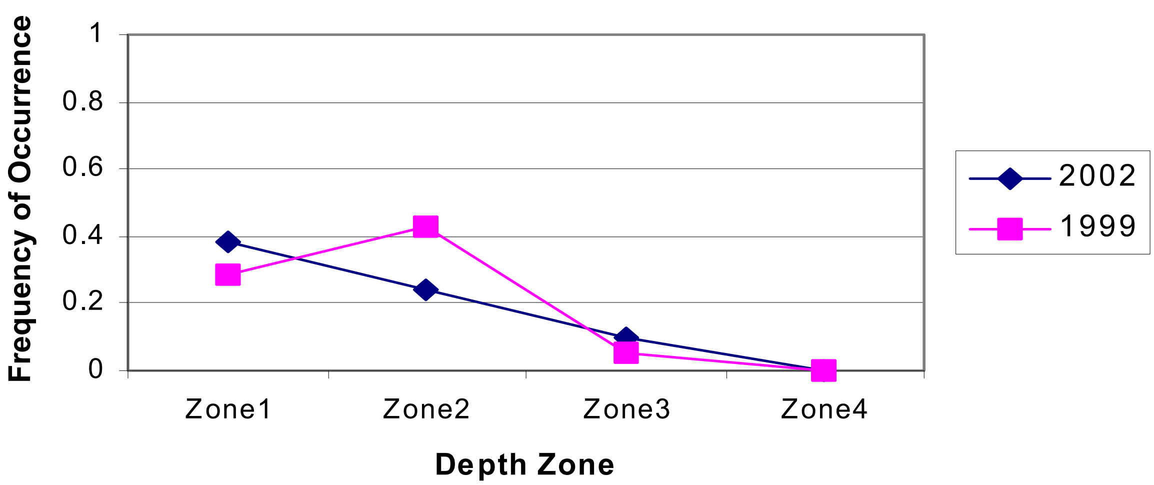

Figure 4. Occurrence of filamentous algae in Pike Lake, 1999-2002.

DENSITY

All mean plant densities were low in Pike Lake in 1999-2002 *Chara* sp. had the highest density (Figure 5), increasing from 1999-2002.

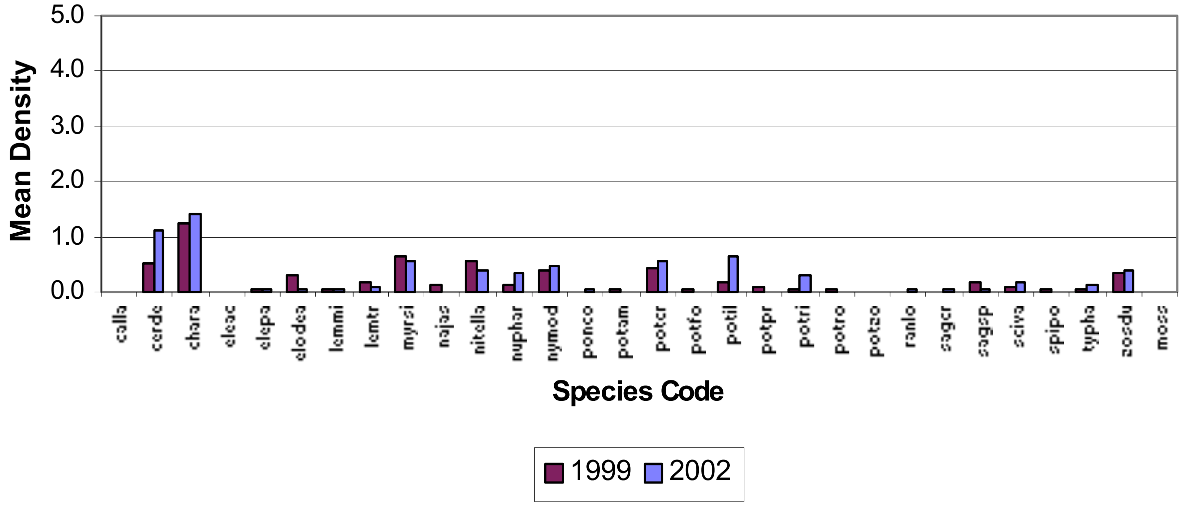

Figure 5. Densities of macrophytes in Pike Lake 1999-2002.

"Density where present" measures how dense of a growth form a species exhibits in a lake. The species may occur in only a few sites and have a low mean density over the entire lake, but in the sites at which it occurs, may exhibit a dense form of growth. *Scirpus validus* was the only species that exhibited a dense form of growth in Pike Lake in 1999 or 2002 (Figure 6). *S. validus* grew at slightly above average densities.

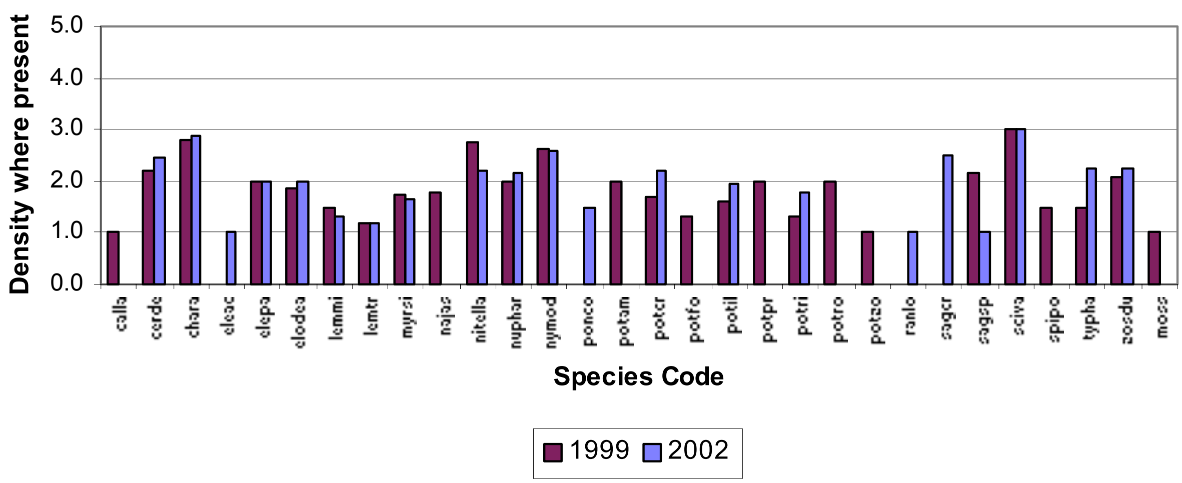

Figure 6. "Density where present" of macrophytes in Pike Lake 1999-2002.

DOMINANCE

Combining relative frequency and relative density into a dominance value illustrates how dominant a species is in its community. The dominance of the prevalent species has varied from year-to-year. This may be due to the past surveys being conducted at different times during the summer. In addition, the 1993 and 1996 surveys were conducted after chemical treatments.

Ceratophyllum demersum and *Myriophyllum sibiricum* were the dominant species in 1989 (Figure 7).

Lemna trisulca became the dominant species in 1993-1996 with *Ceratophyllum demersum* and *Chara* sp. as sub-dominant in 1993 and *C. demersum* as sub-dominant in 1996 (Figure 7).

Chara sp. increased in dominance to become the dominant species in 1999 and 2002, with *Myriophyllum sibiricum* as sub-dominant in 1999 and *Ceratophyllum demersum* as sub-dominant in 2002 (Figure 7).

Figure 7. Dominance of prevalent species in Pike Lake, 1989-2002.

DISTRIBUTION

Aquatic plants occurred throughout the littoral zone during 1989-2002. The depth zone with the highest total occurrence and total density of aquatic plants growth was the 1.5-5ft depth zone during 1989-1996 (Konkel 2002). The highest total occurrence and density of plant growth in 1999-2002 shifted to the 5-10ft depth zone (Figure 8). Total occurrence and density of plant growth was slightly higher in 2002 (Figure 8).

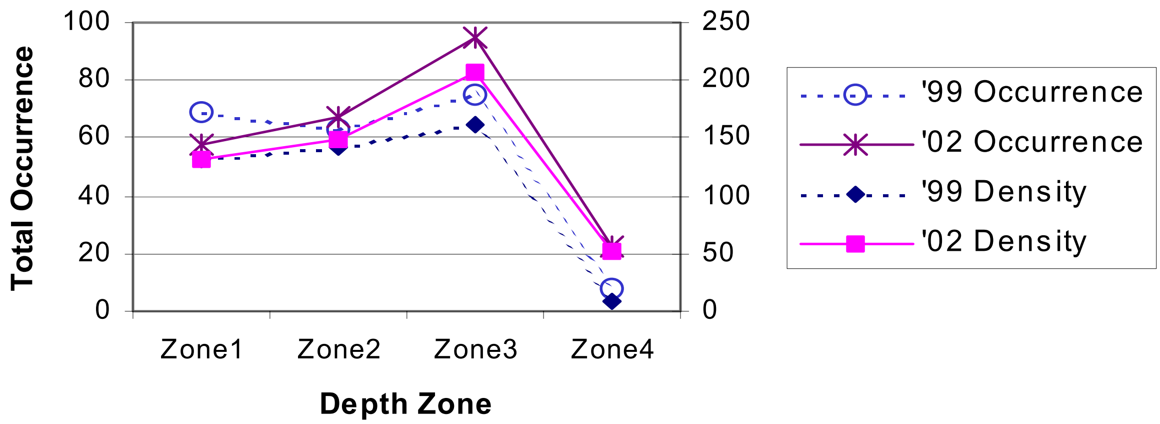

Figure 8. Total occurrence and density of macrophytes by depth zone, Pike Lake, 1999-2002.

The highest percent of vegetated sites was recorded in the 1.5-5ft depth zones 1989-1996 (Konkel 2000). The highest percent of vegetated sites shifted to the 5-10ft depth zone 1999-2002 (Figure 9). Percent of vegetated sites decreased slightly in 2002 (Figure 9).

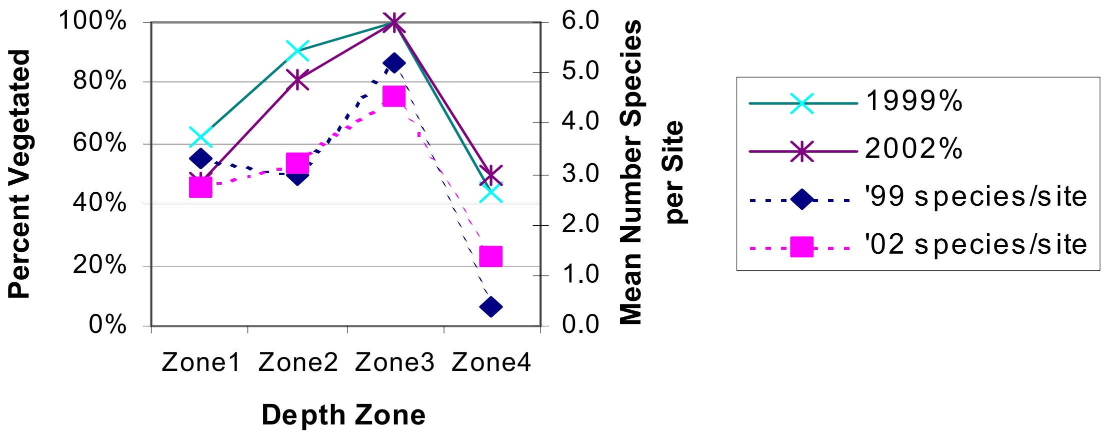

Figure 9. Percentage of littoral zone vegetated and mean number of species per site by depth zone, 1999-2002.

The mean number of species per sample site is an indication of the amount of plant growth and its diversity. The depth zone with the most species per site was in the 1.5-5ft depth zone during 1989-1996 (Konkel 2002). The greatest number of species per site shifted to the 5-10ft depth zone in 1999-2002 (Figure 10).

Chara sp. was the dominant species in 1999-2002, especially in the 1.5-10ft depth zone. *Chara* sp. occurs at its highest frequency and density in this depth zone (Figure 10).

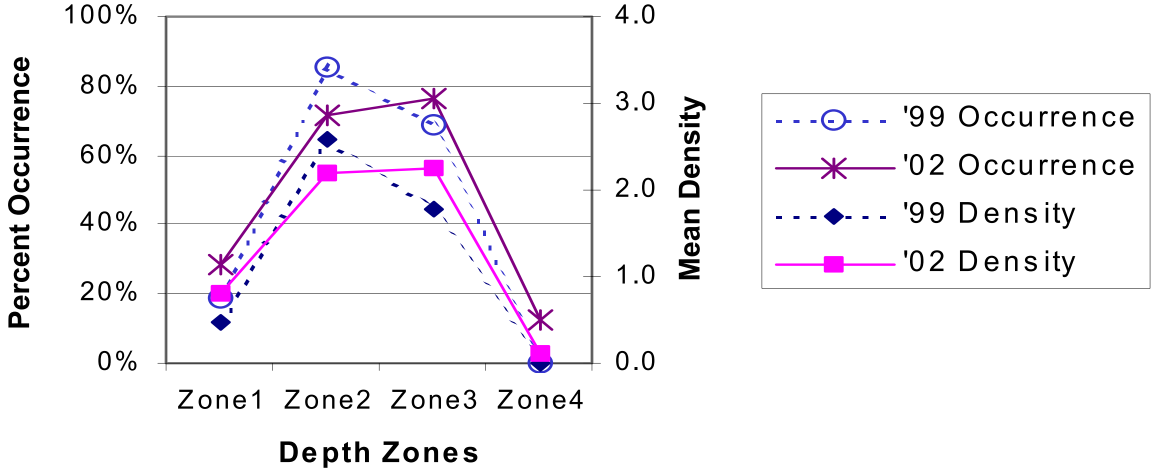

Figure 10. Frequency and density of Chara by depth zone, Pike Lake, 1999-2002.

Ceratophyllum demersum was the dominant species in 1989 and sub-dominant in 1993-1996 and 2002, especially in the shallow depth zone and the 10-20ft depth zone. *C. demersum* has occurred at its highest frequency and density in the 5-10ft depth zone (Figure 11). The frequency and density *C. demersum* increased from 1999 to 2002 (Figure 11).

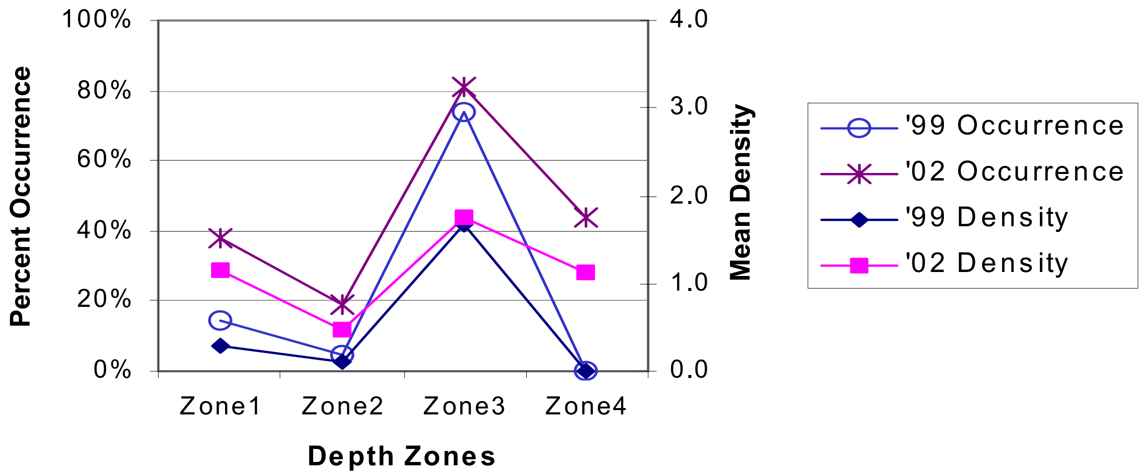

Figure 11. Frequency and density of *Ceratophyllum demersum* by depth zone.

Potamogeton crispus was recorded at low frequencies and densities in 1989 (Konkel 2000). In 1999, *P. crispus* dominated the 10-20ft depth zone and occurred at the maximum rooting depth in 1999-2002. The frequency and density of *P. crispus* has been highest in the 5-10ft depth zone (Figure 12).

Figure 12. Frequency and density of *Potamogeton crispus* by depth zone, Pike Lake, 1999-2002.

SEDIMENT COMPOSITION

Some aquatic plants depend on the sediments for required nutrients. The texture, richness or sterility of the sediment will determine the type and abundance of species that can survive in a location. The availability of mineral nutrients for plant growth is highest in sediments of intermediate density. Silt is an intermediate density sediment that is favorable for plant growth (Barko and Smart 1986). Silt sediments were dominant in Pike Lake and supported high levels of vegetation, both alone and in mixtures with sand (Table 7).

Sand sediment was also commonly encountered in Pike Lake. Sand sediments can be nutrient limiting due to their high density; sand supported vegetative growth at approximately half of the sites at which it occurred in Pike Lake.

Table 7. Macrophyte Occurrence at Sediment

		% Occurrence at Sites	% Vegetated
Soft Sediments	Silt	39%	81%
	Silt/Muck	1%	10%
Mixed Sediments	Sand/silt	14%	100%
Hard Sediments	Sand	29%	56%
	Sand/rock	11%	89%
	Rock	4%	0%

MACROPHYTE COMMUNITY

The Coefficients of Community Similarity indicate that the aquatic plant community in Pike Lake has changed significantly between each survey. The 1999 and 2002 aquatic macrophyte communities were most similar (74%), but still significantly different (Table 8). The most significant change in the plant communities occurred between 1996 and 1999 (only 60% similar) (Table 8). The continual change in the plant community over thirteen years resulted in the 2002 plant community being only 56% similar to the plant community of 1989 (Table 8).

Table 8. Coefficients of Community Similarity Pike Lake 1989-2002.

	Coefficient *	% Similar
1989-1993	0.70075	70%
1993-1996	0.62029	62%
1996-1999	0.60592	60%
1999-2002	0.74186	74%
1989-2002	0.55582	56%

* - Coefficients less than 0.75 indicate a significant difference.

Several indices and parameters can be used to assess what type of changes have occurred within the aquatic macrophyte community to have resulted in the significant change. Some parameters can not be compared because of the difference in sampling procedures between 1989-1996 and 1999-2002 (page 3).

The number of species occurring at the sample sites has decreased since 1999. The percent of the littoral zone vegetated has also decreased (Table 9).

The coverage of emergents species, free-floating and floating-leaf species has increased. Free-floating species have increased the most in coverage (Table 9).

Table 9. Changes in the Pike Lake Macrophyte Community, 1989-2002.

	1989	1993	1996	**1999**	**2002**	Change 1999-2002	%Change 1999-2002
Number of Species	20	27	28	**26**	**21**	-5	-19.2%
% of Littoral Zone Vegetated				**74.7**	**70.9**	-3.8	-5.1%
%Sites/Emergents				**11.4**	**12.7**	1.3	11.4%
%Sites/Free-floating				**30.4**	**45.6**	15.2	50.0%
%Sites/Submergents				**69.6**	**69.6**	0.0	0.0%
%Sites/Floating-leaf				**16.5**	**20.3**	3.8	23.0%

Simpson's Diversity Index	0.93	0.92	0.93	**0.92**	**0.91**	-0.01	-1.1%
Floristic Quality	24.65	29.81	31.40	**27.20**	**25.44**	-1.76	-6.5%

Simpson's Diversity index has continued to decrease since 1989 (Table 9). A Diversity index of 1.0 would mean that each individual in a community was a different species, the most diversity that could be found. These values indicate that Pike Lake has good plant diversity, which may be slowly declining.

The Floristic Quality (discussed later in this document) has increased since 1989 and decreased since 1999 (Table 9).

The actual maximum rooting has been slightly greater than the predicted maximum rooting depth based on summer mean water clarity (Figure 13). This is likely due to better water clarity early in the season when aquatic plants are beginning their growth.

Figure 13. Predicted and actual maximum rooting depth in Pike Lake.

The Aquatic Macrophyte Community Index (AMCI) indicates that the plant community was above average quality in 1999 and decreased to average quality in 2002 (Table 10).

Table 10. Aquatic Macrophyte Community Index Values for Pike Lake, 1999-2002.

	1999	2002
Maximum Rooting Depth	6	6
% Littoral Zone Vegetated	10	10
Simpson's Diversity Index	10	10
Relative Frequency of Submersed Species	8	7
Relative Frequency of Sensitive Species	2	0
# of Taxa (reduced by exotic)	9	7
Total	45	40

The maximum AMCI value is 60
the average AMCI value for Wisconsin lakes is 40.

The aquatic plant communities change, because the plant species in the community change in frequency and density.

Between 1989 and 1999, *Potamogeton zosteriformis, P. praelongus* and *P. robbinsii* decreased substantially. During the same time period, *Potamogeton crispus,* an exotic species, increased noticeably in frequency, density and dominance (Konkel 2000).

The frequency, density and dominance of most other plant species in Pike Lake appeared to fluctuate up and down from one study year to the next (Konkel 2000).

Since 1999, eight species disappeared at the sample sites: 5 pondweed species. Three species were recorded at the sample sites in 2002 that were not recorded in 1999. In addition to the species that disappeared, five species decreased, *Elodea canadensis* decreased the most, 85% (Appendix XVI). Ten species increased in frequency and density at the sample sites between 1999 and 2002. *Potamogeton richardsonii* increased the most, four-fold increase (Appendix XVII).

The Average Coefficient of Conservatism for Pike Lake aquatic plant species was in the lowest quartile for all Wisconsin lakes in 1989, below the mean in 1993, above the mean in 1996 and in the lowest quartile again in 1999-2002 (Table 11). Compared to lakes in the North Central Hardwoods Region, Pike Lake was below the mean in 1989, above the mean in 1993, in the upper quartile in 1996 and below the mean in 1999-2002 (Table 11). This suggests that the plant community in Pike Lake is more tolerant of disturbance than the average lake in the region and among the group of lakes in the state most tolerant of disturbance.

Table 11. Floristic Quality and Coefficient of Conservatism of Pike Lake, Compared to Wisconsin Lakes and Northern Central Wisconsin Lakes.

	(C) Average Coefficient of Conservatism †	**(I) Floristic Quality ‡**	**(I) Based on Relative Frequency**
Wisconsin Lakes	5.5, 6.0, 6.9*	16.9, 22.2, 27.5*	
NCHR Lakes	5.2, 5.6, 5.8*	17, 20.9, 24.4*	
Pike Lake, 1989-1999			
1989	5.38	24.66	21.52
1993	5.84	29.81	27.50
1996	6.28	31.40	26.47
1999	5.44	27.20	26.16
2002	5.30	25.44	19.74

***** - upper limit of lowest quartile, mean, lower limit of upper quartile

***** - North Central Hardwoods Region (NCHR), region within Pike Lake is located

† - Average Coefficient of Conservatism for all Wisconsin lakes ranged from a low of 2.0 (most disturbance tolerant) to a high of 9.5 (least disturbance tolerant)

‡ - The lowest Floristic Quality was 3.0 (farthest from an undisturbed condition) to a high of 44.6 (closest to undisturbed condition)

The Floristic Quality in Pike Lake was above the mean for

Wisconsin lakes in 1989, within the upper quartile in 1993-1996 and above the mean again in 1999-2002. Pike Lake's Floristic Quality was in the upper quartile of lakes in the North Central Hardwoods Region in all years (Table 11).

These values and conclusions were based only on the occurrence of disturbance-tolerant and disturbance-sensitive species. The frequency or dominance of these tolerant or sensitive species in the plant community in Pike Lake was not taken into consideration. The Floristic Quality was recalculated by weighting each specie's Coefficient of Conservatism with its relative frequency.

The resulting values suggest a different conclusion. Based on the relative frequency of the species, the Floristic Quality indicates the plant community in Pike Lake was above the mean or below the mean for all Wisconsin lakes during all study years, 1989-2002. The Pike Lake plant community was above the mean for North Central Hardwood Region Lakes in 1989, within the upper quartile during 1993-1999, and below the mean in 2002 (Table 11).

This suggests that Pike Lake is farther from an undisturbed condition than the average lake in Wisconsin or the region. Disturbance appears to have increased since 1993.

Disturbances can be of many types:

1) Physical disturbances to the plant beds result from activities such as boat traffic, plant harvesting, chemical treatments, the placement of docks and other structures and fluctuating water levels.
2) Indirect disturbances are the result of factors that impact water clarity and thus stress species that are more sensitive: resuspension of sediments, sedimentation from erosion and increased algae growth due to nutrient inputs.
3) Biological disturbances include the introduction of a non-native or invasive plant species, grazing from an increased population of aquatic herbivores and destruction of plant beds by the fish population.

IV. DISCUSSION

Water quality impacts

Pike Lake is a hardwater lake with good water quality and fair-to-poor water clarity. Based on water clarity and concentrations of chlorophyll (algae) and phosphorus (nutrients), Pike Lake has fluctuated on the borderline of a mesotrophic / eutrophic lake during the study period (1989-2002). Nutrients and algae (as measured by phosphorus and chlorophyll) increase over the summer. The agriculture in the watershed, the lawns around the lakeshore and the chemical treatments are likely sources of nutrients to Pike Lake. Filamentous algae was common.

Little of the shoreline on Pike Lake is protected by native plant growth (wooded, shrub and native grasses and wildflowers). Disturbed shoreline (cultivated lawn, hard structures, rip-rap and pavement) occurred at 86% of the sites and covered 55% of the shoreline at the sites. Cultivated lawn was the most abundant disturbed shoreline, covering nearly half of the shore. Lawns and hard surfaces increase run-off to a lake and supply added nutrients to a lake from soil erosion, lawn chemicals and pet waste. Toxic substances also run into the lake from lawn pesticides and paved surfaces.

Regular herbicides treatments have been conducted on Pike Lake since 1940. In an attempt to control algae, at least 3745 pounds of pure copper has been added to the sediments of the lake (records were not regularly kept during the 1940's). Copper does not degrade any further and builds up in the sediment; Pike Lake now contains 18 pounds of copper per acre. This copper is likely more concentrated in the shallow areas of the lake. Mollusks, such as clams, are sensitive to copper in the sediments and can be killed. Since mollusks are natural algae consumers, the copper treatments may have made the algae situation worse.

The sediments in Pike Lake have also been contaminated by applying at least 3560 pounds of arsenic; arsenic does not degrade either, resulting in 17 pounds of arsenic per acre in Pike Lake. The sediments in Pike Lake must be handled as hazardous waste due to the arsenic contamination.

Silvex (which is related to the carcinogen, agent orange) was added in 1968-69; 139.5 pounds.

Hydrothol is one of the formulations of endothall that was applied to Pike Lake during 1976-1994. Hydrothol is more damaging to young fish than other endothall formulations.

Aquatic invertebrates provide important forage for fish and are also sensitive to copper and other herbicides, even at approved rates for application. Regular treatments with herbicides and algacides result in ongoing reductions in the food source of fish.

The poor water clarity could limit plant growth.

Aquatic plant community

Plant growth in Pike Lake is favored by four factors.

1) The hard water
2) The shallow depths and gradually sloped littoral zone over most of the lake
3) The dominance of favorable silt sediments.

4) High nutrients that define a eutrophic/mesotrophic lake.

Aquatic plant growth is distributed at low densities throughout the littoral zone of Pike Lake to a maximum rooting depth of 13 feet. The maximum rooting depth is slightly more than the predicted maximum rooting depth based on water clarity. This is likely due to better water clarity early in the season when plant growth is starting. The depth zone with the greatest amount of plant growth (highest percent of vegetated sites, highest total occurrence and density of plant growth and greatest number of species per site) has shifted from the 1.5-5 ft depth zone to the 5-10 ft depth zone in 1999-2002.

The plant community in Pike Lake is of average quality for Wisconsin lakes with good species diversity. Pike Lake is more disturbance tolerant and farther from an undisturbed condition than the average lake in Wisconsin or the region. This is likely due to being subjected to a greater than average amount of disturbance. The chemical treatments and the poor water clarity that results from the treatments are likely the major disturbance factors in Pike Lake.

A total of 38 aquatic plant species were found during the plant surveys and the dominant species were distributed throughout the lake. The dominant species have shifted from coontail (*Ceratophyllum demersum)* and northern watermilfoil *(Myriophyllum sibiricum)* in 1989 to muskgrass (*Chara* sp). and coontail in 2002. Muskgrass was more prevalent in the 1.5-10ft depth zones and coontatil was more prevalent in the 0-1.5 and 10-20ft depth zones. *Scirpus validus* (softstem bulrush) was the only species that occurred at above average densities in 1999-2002.

Changes in the aquatic plant community

Significant changes have occurred in the aquatic plant community in Pike Lake. The Coefficient of Similarity between indicates that the 1999 and 2002 plant communities are only 74% similar. Enough change has occurred within the plant community during 1989-2002 that the 1989 plant community is only 56% similar to the 2002 plant community.

The major changes that have occurred within the aquatic plant community in Pike Lake:

Since 1989, species diversity has decreased.

A non-native pondweed, *Potamogeton crispus* has increased.

Since 1999,

a) the quality of the plant community has declined (measured by AMCI) from above average quality in 1999 to average quality in 2002
b) disturbance in the plant community has increased as measured by Floristic Quality
c) the number of species has declined
d) the total occurrence and density of plant growth has increased
e) the percent of the littoral zone that is vegetated has decreased
f) the coverage of emergent and floating-leaf

vegetation has increased

g) the coverage of free-floating vegetation has increased substantially (50% increase)

Besides changes in the dominant species during 1989-2002, some species have suffered a steady decline. White-stem pondweed (*Potamogeton praelongus*),fern-leaf pondweed (*Potamogeton robbinsii*), flatstem pondweed (*Potamogeton zosteriformis*) and softstem bulrush (*Scirpus validus*) have declined. The pondweeds are excellent fish habitat and the bulrush is excellent fish and wildlife habitat.

One species that has increased, curly-leaf pondweed (*Potamogeton crispus*), is a non-native species that can become invasive.

The occurrence and density of some individual species have fluctuated. This is likely due to the lack of consistency in sampling the 10-20ft depth zone during 1989-1996 and the variation in the timing of the aquatic plant surveys with the chemical treatments (Table 14). The survey in 1989 was not impacted by a chemical treatment, the 1993 and 1996 surveys were conducted after chemical treatments. The 1999 and 2002 plant surveys was conducted early to prevent sampling after a chemical treatment (Table 14). The 2002 chemical treatment was conducted on the same day as the survey, by starting treatment mid-day and starting on the portion of the lake already sampled. Conducting surveys after a chemical treatment and conducting surveys too early in the season to avoid a chemical treatment can bias the plant survey.

Table 14. Survey dates and Chemical Treatments

Survey Date	**Chemical Treatment**
7/17/89	No Treatments since 1984
8/25/93	6/21/93 & 7/19/93
7/10/96	6/24/96 & 7/22/96
6/28/99	6/30/99 & 7/26/99
6/24/02	6/24/02 & 7/23/02

V. CONCLUSION

Pike Lake is a eutrophic/mesotrophic, hardwater lake with good water quality and fair-to-poor clarity. The nutrients and algae increase during the summer (Figure 14). This increase may be due to the chemical treatments that leave plant material in the water to decay.

Figure 14. Increase in nutrients and algae in Pike Lake during the summer.

Aquatic plant growth in Pike Lake is favored by the broad zones of shallow depth, the gradually sloped littoral zone, hardwater, silt sediments and abundant nutrients.

The aquatic plant community in Pike Lake is characterized by good species diversity, average quality, impacted by above average mount of disturbance, abundant frequency of plants and low density of plant growth. The dominant plant species in 2002 were muskgrass and coontail.

Aquatic plants are distributed throughout the lake, up to a maximum rooting depth of 13 feet. The depth zone of most abundant plant growth has shifted from the 1.5-5ft depth zone in 1989-96 to the 5-10ft depth zone in 1999-2002. Aquatic plant growth is more sparse in the southeast half of the lake.

Healthy aquatic plant communities provide many invaluable benefits to the lake ecosystem. The native plant community improves water quality, provides the fish and wildlife habitat in a lake, resist the invasion of non-native plant species and check excessive growth of more aggressive species.

The plant community can improve water quality in many ways:

1) trapping nutrients, debris, and pollutants entering a water body;
2) absorbing and breaking down some pollutants;
3) stabilizing banks and shorelines that prevents erosion
4) stabilizing the lake bottom that prevents sediment resuspenion from wave action;
5) using and removing nutrients that would otherwise be available for algae blooms (Engel 1985).

Aquatic plant beds offers valuable fish and wildlife habitat. Plants start the food chain in a lake while producing oxygen that is needed by all other life in the lake. Invertebrates living on and beneath the plants are prime food sources for wildlife and fish. Plant beds provide shelter for young and adult fish and spawning sites for many species. They are used as nesting sites and cover by wildlife species.

The structure and density of the plants determine the foraging success of the predatory fish, which impacts balance in the fish community. Sparse plant growth results in fewer prey fish, while dense plant growth is overly protective of the prey fish. The plants in the Pike Lake provide between 25-85% cover at the sample sites, which is appropriate for a balanced fishery.

The aquatic plant community in Pike Lake has undergone changes. The composition of the plant community has changed significantly. The 1999 plant community is only 74% similar to the 2002 community; the 2002 plant community is only 56% similar to the 1989 plant community. The total occurrence and density of aquatic plant growth has increased.

The changes in the aquatic plant community that are disturbing are:

8) The dominant species in the plant community have changed. The aquatic plant community has shifted from a coontail and northern watermilfoil dominated community in 1989 to a muskgrass and coontail dominated community in 2002. As an annual, muskgrass, germinates easily when the existing plant cover is removed. The chemical treatments may be causing the increase in dominance of muskgrass by opening areas up for it to colonize. Coontail is less valuable for fish habitat due to its habit of matting together. As a free-floating species increases in coontail may be triggered by poor water clarity.
9) A non-native plant species has increased. Curly-leaf pondweed has increased over the fourteen year study. Broad spectrum treatments during the growing season are likely causing this species to increase.
10) Plant species diversity has decreased since 1989. Decreased diversity of the plant community provides less diversity in the habitat, which will impact the size and diversity of the wildlife and fish population in the lake.
11) Disturbance in Pike Lake has increased as measured by the decrease in Floristic Quality. Poor water clarity, disturbed shoreline and chemical treatments are likely the disturbance factors in Pike Lake.
12) The quality of the plant community has decreased (AMCI).
13) Free-floating aquatic plant species have increased (50% increase) in coverage in Pike Lake. Increases in free-floating species suggest declining water clarity. Since they float on the surface, they are not impacted by clarity and can take advantage of the nutrients that are no longer being used by the submergent species.
14) A few species of native pondweeds which are a valuable for habitat have declined.

Management Recommendations

7) Pike Lake needs a buffer zone of natural vegetation around the lakeshore. Far too much shoreline is covered by lawn and subject to run-off and input of nutrients and toxics. Currently, more than half of the shoreline is disturbed; cultivated lawn alone covers nearly half of the shoreline. On shore, a buffer zone of native grasses, flowers, shrubs and trees are needed to replace the cultivated lawn.
8) Plant emergent aquatic plants to replace rip-rap commonly found around the lake. Living plants are more effective at protecting the shoreline from erosion than rip-rap and rock walls.
9) Cooperate with efforts in the watershed to reduce erosion and fertilizer run off into Pike Lake.
10) Eliminate fertilization of shoreline properties.
11) Any project in Pike Lake involving the sediments would require prior analysis of the sediments to determine the extent of the arsenic contamination.
12) Explore alternatives to the use of broad-spectrum chemicals for reducing native plant growth and implement their use.
    a.) Reducing plant growth by application of chemicals

allows the plant material to remain in the water. The decay of plant material releases nutrients that feed algae growth. The decayed plants enrich the sediments and continue the cycle of more plant growth. This phenomenon is seen in the increase in nutrients and algae that occur during the summer (Figure 14) and the increase in free-floating plant species in Pike Lake.

b.) Using a broad-spectrum chemical removes all plant material, providing a perfect location for the colonization of more opportunistic plant species. This is seen in the increased dominance of muskgrass, the increase of the exotic species, curly-leaf pondweed and the loss of some more valuable species.

c.) The decay of the chemically treated plant growth results in increased algae growth that leads to copper treatments. The copper is toxic to important parts of the food chain in the lake and builds up in the sediment, becoming toxic to mollusks, which are the natural algae consumers in a lake.

Pike Lake is a valuable wildlife and fish resource for Marathon County. Management of the lake should focus on preserving the long-term quality of the lake.

Pike Lake Aquatic Plant Species, 1989-1999

Scientific Name	Common Name	I. D. Code
Emergent Species		
1) *Calla palustris*	water arm	calpa
2) *Carex rostrata*	sedge	carro
3) *Dulichium arundinaceum*	three-way sedge	dular
4) *Eleocharis palustris*	creeping spikerush	elepa
5) *Equisetum fluviatie*	scouring rush	equfl
6) *Juncus* sp.	rush	junsp
7) *Pontederia cordata*	pickerelweed	ponco
8) *Sagittaria cristata*	arrowhead	sagcr
9) *Sagittaria* sp.	arrowhead	sagsp
10) *Scirpus validus*	softstem bulrush	sciva
11) *Typha latifolia*	broad leaf cattail	typla
Floating leaf Species		
12) *Brasenia schreberi*	watershield	brasc
13) *Lemna minor*	small duckweed	lemmi
14) *Lemna trisulca*	forked duckweed	lemtr
15) *Nuphar variegata*	bull-head pond lily	nupva
16) *Nymphaea odorata*	white water lily	nymod
17) *Spirodela polyrhiza*	great duckweed	spipo
Submergent Species		
18) *Ceratophyllum demersum*	coontail	cerde
19) *Chara* sp.	muskgrass	chasp
20) *Eleocharis acicularis*	needle spikerush	eleac
21) *Elodea canadensis*	common waterweed	eloca
22) *Juncus pelocarpus*	rush	junpe
23) *Myriophyllum sibiricum*	common water milfoil	myrsi
24) *Najas flexilis*	slender naiad	najfl
25) *Nitella* sp.	nitella	nitsp
26) *Potamogeton amplifolius*	large-leaf pondweed	potam
27) *Potamogeton crispus*	curly-leaf pondweed	potcr
28) *Potamogeton foliosus*	leafy pondweed	potfo
29) *Potamogeton illinoensis*	Illinois pondweed	potil
30) *Potamogeton pectinatus*	sago pondweed	potpe
31) *Potamogeton praelongus*	whitestem pondweed	potpr
32) *Potamogeton richardsonii*	clasping-leaf pondweed	potri
33) *Potamogeton robbinsii*	fern pondweed	potro
34) *Potamogeton zosteriformis*	flatstem pondweed	potzo
35) *Ranunculus longirostris*	stiff water crowfoot	ranlo
36) *Utricularia* sp.	bladderwort	utrsp
37) *Vallisneria americana*	water celery	valam
38) *Zosterella dubia*	water stargrass	zosdu